

1
2 1. An apparatus for providing chemical and biological detection of molecules
3 adsorbed on an organic self-assembled surface, comprising:

4 a gate contact;

5 a gate insulator attached to the gate contact;

6 a source contact attached to the gate insulator;

7 a drain contact attached to the gate insulator; and;

8 a semiconductor layer extending between the source and drain comprising
9 an organic monolayer of molecules, each molecule comprising a sensing end
10 group, a conjugated segment covalently bonded to the sensing end group, and an
11 attaching end group covalently bonded to the conjugated segment and attached to
12 the gate insulator.

13 2. The apparatus as recited in claim 1, wherein the sensing end group is
14 selected from the group consisting of halides, nitriles, amines, amides, and ketones.
15

16 3. The apparatus as recited in claim 1, wherein the attaching end group is
17 selected from the group consisting of trichlorosilyl groups, amines, and carboxylic acid
18 groups.
19

20 4. The apparatus as recited in claim 1, wherein the conjugated segment is
21 selected from the group consisting of phenyl-acetylene and phenylene-vinylene.
22
23
24

1 5. The apparatus as recited in claim 1, configured such that adsorbed
2 molecules can be selectively removed from the sensing end group by heating the organic
3 self-assembled monolayer and driving off adsorbed species of vapor molecules.

4
5 6. The apparatus as recited in claim 1, wherein the sensing end group
6 generates an atomically sharp interface for differentiating between vapor molecules.

7
8 7. The apparatus as recited in claim 1, wherein a substance is detected when
9 the sensing end group adsorbs a threshold amount of a desired vapor molecule.

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

MADSON & METCALF, P.C.
ATTORNEYS AT LAW
900 GATEWAY TOWER WEST
SUITE 2000
SALT LAKE CITY, UTAH 84101

1
2 8. An organic self-assembled transistor fabricated on a silicon substrate, the
3 transistor comprising:

4 a gate contact;

5 a gate insulator attached to the gate contact;

6 a source contact attached to the gate insulator;

7 a drain contact attached to the gate insulator; and

8 a semiconductor layer between the source and drain, the layer comprising
9 an organic self-assembled monolayer of molecules.

10 9. The transistor as recited in claim 8, wherein the organic self-assembled
11 monolayer comprises a pentacene film.

12
13 10. The transistor as recited in claim 9, wherein the pentacene film is about
14 10nm thick.

15
16 11. The transistor as recited in claim 8, wherein each molecule of the organic
17 self-assembled monolayer comprises:

18 a sensing end group;

19 a conjugated segment covalently bonded to the sensing end group; and

20 an attaching end group covalently bonded to the conjugated segment and
21 attached to the gate insulator.

22 12. The transistor as recited in claim 11, wherein the sensing end group can be
23 changed to control the chemical properties of the sensing surface.
24

MADSON & METCALF, P.C.
ATTORNEYS AT LAW
900 GATEWAY TOWER WEST
SUITE 1500
SALT LAKE CITY, UTAH 84101

1 13. The transistor as recited in claim 11, wherein the organic self-assembled
2 monolayer generates an atomically sharp interface for differentiating between vapor
3 molecules via the sensing end group.

4
5 14. The transistor as recited in claim 11, wherein the sensing end group is
6 selected from the group consisting of halides, nitriles, amines, amides, and ketones.

7
8 15. The transistor as recited in claim 11, wherein the conjugated segment is
9 selected from the group consisting of phenyl-acetylene and phenylene-vinylene.

10 16. The transistor as recited in claim 11, wherein the attaching end group is
11 selected from the group consisting of trichlorosilyl, amines, and carboxylic acid groups.

12
13 17. The transistor as recited in claim 11, wherein charge carrier density of the
14 sensing end group changes according to the adsorption of vapor molecules.

15 18. The transistor as recited in claim 11, wherein charge mobility of the
16 sensing end group changes according to the adsorption of vapor molecules.

17
18 19. The transistor as recited in claim 11, wherein current pulses heat the
19 organic self-assembled monolayer so that adsorbed species of vapor molecules are
20 removed from the sensing end group.

21 20. The transistor as recited in claim 19, wherein the energy required to heat 3
22 $\times 10^{-13} \text{ cm}^3$ of the organic self-assembled monolayer is about 15 pJ.
23
24

MADSON & METCALF, P.C.
ATTORNEYS AT LAW
900 GATEWAY TOWER WEST
SUITE 2000
SALT LAKE CITY, UTAH 84101

21. The transistor as recited in claim 11, wherein the sensing end group may be removed and replaced without removing the conjugated segment or the attaching end group.

MADSON & METCALF, P.C.
ATTORNEYS AT LAW
900 GATEWAY TOWER WEST
SUITE 2000
SALT LAKE CITY, UTAH 84101

1
2 22. A process of making an organic self-assembled transistor on a silicon
3 substrate, the process comprising the steps of:

4 high-temperature processing of the silicon to generate a substrate, a gate, a
5 gate insulator, a source and a drain for the transistor; and

6 depositing an active organic monolayer between the source and drain, the
7 active monolayer attaching to the gate insulator via an attaching end group.

8 23. The process as recited in claim 22, wherein the active organic monolayer
9 is deposited using micro-contact printing.

10 24. The process as recited in claim 23, wherein the depth of the active organic
11 monolayer is between about 3nm and about 10nm.

12 25. The process as recited in claim 22, wherein the depth of the active organic
13 monolayer is less than about 10nm.

14 26. The process as recited in claim 22, wherein differential response
15 characteristics of the active organic monolayer vary according to concentration levels of
16 adsorbents on the surface of the monolayer.
17
18
19
20
21
22
23
24

1
2 27. The process as recited in claim 22, wherein the active organic monolayer
3 comprises a conjugated segment covalently bonded to said attaching end group and a
4 sensing end group covalently bonded to said conjugated segment.

5 28. The process as recited in claim 27, wherein the sensing end group can be
6 changed to control the chemical properties of the sensing surface.

7
8 29. The process as recited in claim 27, wherein said attaching end group is
9 chemically bonded to the gate insulator.

10 30. The process as recited in claim 22, wherein the substrate is a silicon
11 substrate and wherein the contacts are metals.

12
13 31. The process as recited in claim 30, wherein the contacts are selected from
14 the group consisting of gold, aluminum, silver, platinum, copper, lithium, calcium, and
15 combinations thereof.

16
17 32. The process as recited in claim 22, wherein the gate insulator is a high
18 dielectric constant oxide.

19
20 33. The process as recited in claim 32, wherein the gate insulator is yttria
21 stabilized zirconia.

22 34. The process as recited in claim 32, wherein a dielectric constant of the
23 gate insulator is greater than about 4.
24

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

35. A chemical and biological sensor array system, the system comprising:
an array of organic self-assembled single transistor sensors;
a processing module; and
silicon circuitry connecting the array to the processing module.

36. The system as recited in claim 35, the array of organic self-assembled transistors further comprising at least two organic self-assembled transistor sensors calibrated to detect different vapor molecules.

37. The system as recited in claim 36, wherein the processing module monitors differential responses from organic self-assembled transistors in the array, the processing module detecting changes in the differential responses associated with the adsorption of vapor molecule species.

38. The system as recited in claim 35, wherein the silicon circuitry configured such that the transistor sensors can be packaged as an integrated circuit where the organic self-assembled transistor sensors are exposed to the testing atmosphere.

39. The system as recited in claim 35, wherein the organic self-assembled single transistor sensor comprises:
a transistor including a source, a drain, a gate, and a gate insulator; and
a semiconductor self-assembled monolayer channel bonded to the gate insulator between the source and drain of the transistor, the monolayer changing charge mobility and charge density upon adsorption of vapor molecules.

1 40. The system as recited in claim 39, wherein the monolayer comprises
2 individual organic monolayer molecules for self-assembly covalently bonded to other
3 surrounding organic monolayer molecules.

4
5 41. The system as recited in claim 40, wherein the monolayer provides
6 maximum response when each of the molecules adsorbs a desired vapor molecule.

7
8 42. The system as recited in claim 39, wherein the monolayer provides
9 measurable transistor response changes to low concentrations of less than 10^{-16} moles of
10 analyte molecules.

11 43. The system as recited in claim 39, wherein the monolayer provides
12 maximum response in the presence of analyte molecules even at low concentrations of
13 about 10^{-16} moles.

MADSON & METCALF, P.C.
ATTORNEYS AT LAW
900 GATEWAY TOWER WEST
SUITE 1400
SAN FRANCISCO, CALIF. 94104
TELEPHONE (415) 774-1100
FACSIMILE (415) 774-1101
E-MAIL: M&M@MADSONMETCALF.COM